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NOTES ON THE GENESIS AND HORIZONS OF THE SERPENTINES OF SOUTHEASTERN PENNSYLVANIA.

BY THEODORE D. RAND.

Except the serpentine and steatite of Chestnut Hill, north of Easton, Pa., the outcrops considered in these notes lie not far from the Laurentian anticlinal which enters the State at Morrisville, opposite Trenton, N. J., and extends in an almost unbroken belt to the Maryland line. In width it varies. Generally narrow northeast of the Schuylkill, but usually a prominent ridge, it sinks near Abingdon to appear again southwest of Jenkintown for two or three miles. At Chestnut Hill and the Wissahickon it again disappears for a short distance, rising again to great elevation (350–400 feet) with a width of nearly a mile at the Schuylkill.

Mr. Hall's map shows the Laurentian crossing the Wissahickon on the southwest flank of Chestnut Hill, Philadelphia, northwest of Thorp's lane, and Dr. Hunt[1] speaks of the schists appearing on the *north* side of the narrow Laurentian belt at Chestnut Hill. I have been unable to find a trace of Laurentian along the Wissahickon or at Chestnut Hill except on Paper Mill Lane on the northwest flank of Chestnut Hill.

Southwest of the Schuylkill it preserves its elevation, its summits nearly or quite 500 feet above tide, and it widens, until at Darby Creek it is at least three miles wide, and north and south of Newtown Square at least six, though in this longitude there may be included some schist areas; but the margins at Devon Inn, and south of Berwyn, on the north, and Sycamore Mills on the south, are well defined and exhibit the steep slopes with abundant outcrops so characteristic of this group. Southwest of this the northerly margin trends about S. S. W., passing West Chester one mile north of the Court House, while the southerly margin, defined between Ridley and Chester Creeks along Dismal Run by a precipitous hill of 200 to 300 feet elevation, becomes ill defined, but as observed by Prof. Rogers[2] probably takes a direction nearly west through or near Howellville, Delaware Co., and Westtown, in Chester Co., the belt narrowing to less than three miles.

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[1] Min. Phys. and Phys: p. 437.

[2] 1st Geol. Survey of Pa., Vol. 1, p. 77.

Mr. Hall regards the rocks along Chester Creek from a mile south of Lenni to Cheyneys station, except a narrow belt at Glen Mills, as Laurentian underlying the schists and exposed by the deeper erosion along the creek,[1] but they are so unlike any of the rocks in the admitted Laurentian belt and bear so close a resemblance to the harder gneisses of the Manayunk series that I believe Prof. Rogers' observations to be correct and that the Laurentian is included between gently curved and almost straight lines and that it does not present the contorted outline shown on Mr. Hall's map. These rocks are more fully described in connection with the Glen Mills serpentine. In the northwesterly boundary also of the Laurentian my observations confirm those of Prof. Rogers. Mr. Hall's map makes a schist area overlie the Laurentian from Bryn Mawr to Wayne.[2] In this area, I have described[3] many outcrops of typical Laurentian, well exposed, with not a trace of the schists west of Rosemont except the narrow belt on the northwest of the Laurentian along the bottom of Cream Valley.

To define these areas more exactly will require very close and careful observations of excavations hereafter made, for the covering of soil in many places is so great that only thus can the underlying rocks be known.

This Laurentian belt is the third of Prof. Rogers. Immediately southeast of it lies his second belt, and southeast of the second his first. Of these he writes, and most accurate are his descriptions:—

> THE FIRST or most southern general division or group, may be approximately defined as extending from the lowest exposures on the river, or those near Gray's Ferry, to the upper end of Manayunk; the second or middle belt, extending from Manayunk past the serpentine and soapstone range to a line a little north of the upper boundary of the County or City of Philadelphia; and the third or northern extending thence to the northern edge of the whole gneiss formation, and it is overlaid or limited by the older primal rocks in the vicinity of Spring Mill.
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> FIRST BELT. The southern or Philadelphia belt contains the following chief descriptions of ordinary gneissic rock, with many subvarieties. The most common or typical variety of all is the gray, bluish, rather finely laminated triple mixture of quartz, feldspar and mica, the quartz for the most part, white or transparent; the feldspar usually white, and very generally somewhat chalky from incipient decomposition; and the mica most commonly black or dark brown and in small plates. This rock occasionally includes small insulated garnets.
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> The next most common species is a dark bluish-gray, sometimes greenish-black gneiss, composed of hornblende and quartz, with sometimes a little feldspar, the hornblende always greatly predominating. The rock is very usually fine grained and thinly bedded, its fracture and structure being controlled by the general parallel crystallization of the prevailing hornblende.

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[1] 2nd Geol. Survey of Pa., C^5 p. 2.

[2] C^5 22.

[3] 2nd Geol. Survey of Pa., An. Rep. 1886, IV, p. 1573, etc.

A third common variety of the gneiss of this group is a micaceous quartzose rock, generally of a light gray color. Some beds of this species contain such a predominance of the crystalline quartz, in minute granular divisions, and such a subordinate amount of minutely disseminated mica, as to have a character of ordinary gray whetstone; but this species of the gneiss is much more abundant in the middle belt than in the southern one. A much coarser kind of gray micaceous gneiss, consisting of a predominance of rather large flakes of mica, with a subordinate quantity of feldspar and quartz, occurs interstratified with all these other species, as a very usual transition variety between the standard gray gneiss and the highly micaceous kinds verging toward mica-slate.

It is very usual to find the typical gneiss, of a three-fold constitution, alternating with the hornblende species, and both of these alternating with the quartzose micaceous variety. As a general fact, not without exceptions, however, the more micaceous the rock is, the greater is the abundance in insulated crystals of common garnet.

Interposed among the above varieties of true gneiss are beds, more or less thick, of kinds so abounding in mica as to be entitled to the designation of true mica-slate. This rock prevails in two or three outcrops, both above and below Columbia Bridge, and it may be stated generally, that the further north we advance across the southern division of the gnèiss, the larger is the proportion of the more micaceous varieties of the ordinary gneiss, and the greater the frequency of these bands of mica-slate.

An interesting variety of the ordinary or more feldspathic kind, is one containing large, more or less insulated segregations of crystalline feldspar, the longer axes of whose crystals lie generally parallel with the lamination of the rock. This variety may be designated as a porphyritic gneiss, having that feature of an excess of crystalline feldspar which is accepted by geologists as a distinctive character of the porphyritic rocks and being, moreover, essentially similar to those well-known and beautiful granites which geologists agree to call Porphyritic.

A band of this porphyritic gneiss occurs at the Falls of Schuylkill, just below the quarries, and ranges toward Nicetown in one direction, and toward the tollgate at the Lancaster Road, five miles west of Philadelphia, in the other. Another outcrop of the same feldspathic variety of the gneiss may be seen crossing the West Chester Plank Road just east of Darby Creek.

THE SECOND OR MIDDLE BELT. The middle zone of the gneiss of Southern Pennsylvania, as it crosses the Schuylkill, consists of an alternation of four principal varieties. Perhaps the most abundant of these is a very micaceous species of the ternary or mica, quartz and feldspar rock, holding garnets in greater or less profusion. A ver common feature in this rock is a wavy or minutely undulated lamination, arising apparently from a contorted or wavy structure in the coarsely crystallized mica, its predominant mineral. This would seem to proceed from the interference of the innumerable planes of cleavage, or—what is the same thing—of crystalline lamination, with the original planes of the deposition of strata. The twisted forms of the flakes of mica are frequently seen to be due to the displacing effect of grains, or crystalline bunches of included quartz. It would seem as if these minerals had crystallized or segregated, from their parent sedimentary materials, under a conflict of forces, the newly awakened crystalline energies being not always parallel to the original bedding of the deposit, but more frequently oblique to it.

Perhaps the most common subdivision of the gneiss of this middle tract is a variety consisting almost exclusively of the above described wavy mica. This rock graduates into the more micaceous sorts of gneiss, by containing a less or greater mixture of finely granulated crystalline quartz or feldspar or hornblende. The southern half of the gneissic zone before us is characterized on the Schuylkill and Wissahickon, by containing an alternation of the above two varieties of micaceous gneiss or mica-slate, with beds of hornblende gneiss, the last-named rock being, from its thin lamination, sometimes entitled to the name of hornblende slate. The northern half of the zone consists largely of a fourth variety of the more schistose class of the gneissic rocks. This is a gray fine grained binary mixture of granular quartz and minutely crystallized scales of mica, the quartz being the prevailing element. It is a species of whetstone and some of the more quartzose bands would furnish masses well suited for employment as whetstones for scythes. A very common, indeed a characteristic of this quite remarkable and extensive division of the micaceous gneiss group, consists in its peculiar fracture; the rocks breaking into long narrow chunks, comparatively smooth on their sides, but excessively ragged on their ends; a style of fracture strongly resembling that of half rotted fibrous wood. This peculiar rock is in greatest force toward the northern side of the middle gneiss belt, or between the serpentine or steatite, and the hard feldspathic gneiss of the southern margin of the third or northern gneissic belt. It is interstratified toward its southern side, with more or less frequent and thick bodies of the other variety of mica slate possessing mica in large and twisted scales, with an abundance of garnets. On its northern side it alternates to some extent with a greenish talcose slate, or, what is the same thing, the talc in this quarter replaces the mica in whole or in part in certain divisions of the group."

There is probably in the rock termed by Rogers "altered primal" (whatever may be its geological age) a key rock, for this seems to lie quite persistently along both edges of the Laurentian though only occasionally visible. West of the Schuylkill it is well exposed, but it may be seen also at Willistown and near Westtown, Chester Co. It is thus described by Prof. Rogers, p. 154:—

"In the district of the Schuylkill and Wissahickon, the three members of which the primal series there consist, present the following aspects and dimensions:

The lowest or semi-porphyroidal group, evidently an altered sandy-slate or argillaceous sandstone, is remarkable for the regular parallelism of its lamination and bedding; the laminæ alternately light and dark, being exceedingly thin, many of them usually packing within the thickness of an inch. These laminæ consist, where the rock wears its most metamorphosed form, of white earthy imperfectly developed feldspar, and perfectly developed hornblende. Besides these alternate whitish and dark streaks, the cross fracture of the rock displays a multitude of ovoidal concretionary crystallizations, generally only specks in size, but sometimes of the dimension of bullets, the larger and better formed concretions being frequently genuine crystals of feldspar. In some of the layers certain laminæ are studded with isolated crystallizations of hornblende." 1st Geological Survey of Pennsylvania, Vol. 1, Page 68.

Mr. Hall divides Rogers' first and second groups into three, inserting a belt (the Manayunk schists) between Rogers' first and second [1] and states that it contains "alternations of the varieties of gneiss characteristic of the first belt and a predominance of sandy gneiss composed of quartz and a small amount of feldspar and mica in minute flakes. Mica schists and hornblendic slate alternate with finer grained gneisses, the mica usually light colored." He further states that it includes part of Rogers' second belt.

It is possible that this arises from a misunderstanding of Prof. Rogers' use of the term "upper end of Manayunk," which is evidently used loosely. Rogers says "approximately defined." Inasmuch as just above Manayunk the more massive and less garnetiferous schists of the first belt are well exposed, while about two miles above the centre of Manayunk the rocks of his second belt occur in most characteristic form, is it not most probable Prof. Rogers intended to refer to this point, especially, as when he wrote there was no well known place nearer than Manayunk? Mr. Hall's term, however, is convenient, but I regard it, and use it in these notes, rather as a synonym for all of Rogers' first belt except the Fairmount gneiss, and the porphyritic gneiss.

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[1] 2nd Geol. Surv. Penna. C^6 p. 2.

By far the best exposure of these rocks as described is along the Schuylkill, but the structure is far from clear. The Fairmount gneiss, identical with the gneiss at the Chester, Leiperville and Avondale quarries is generally supposed to underlie the more micaceous rocks to the northwestward, yet almost everywhere is a pretty uniform northerly dip. There are alternations of soft highly micaceous schists passing by an increase of quartz and feldspar and decrease of mica into gneissoid schists and gneiss, also hornblende schists and gneisses, but in no case, except perhaps northwest and southeast of the porphyritic gneiss can a repetition be found to prove the apparent monoclinal to be, as it has been supposed to be, a succession of compressed synclinals and anticlinals.

To the southeastward, the rocks as a rule are highly micaceous, and in these the Fairmount gneiss appears to rise as an anticlinal. In the cut of the Pennsylvania Railroad, about 33rd Street, the southeasterly dip at a moderate angle was clearly shown ; the northwesterly edge has not been uncovered, but the strata were nearly horizontal and were succeeded by mica schist within a hundred yards.

The mica schists are visible southeast of the Fairmount gneiss, with gentle undulating dips, on the west side of the Pennsylvania Railroad near Powelton Avenue, and on both sides, at the approach to the tunnel at 31st and Market Streets ; northwestward of the Fairmount gneiss are alternations of mica schists, micaceous gneiss, hornblendic gneiss and allied rocks to the Falls of Schuylkill.

On the Schuylkill a short distance west of the Girard Avenue bridge there was exposed a rock, mica schist on the outside, hornblende schist within, and the passage of the one into the other was evident. At the quarry (now a coal yard) on the Germantown road at the crossing of the Germantown branch of the Reading Railroad, a similar change was apparent, the micaceous mineral here being the Philadelphite. May not these occurrences throw light upon the fact that the hornblende rocks are more abundant in the deeper valleys and upon the remarkable alternation of hornblende schist and mica schist?

At the Falls of Schuylkill we find the porphyritic gneiss before spoken of. This porphyritic gneiss Mr. Hall does not mention. Prof. Rogers regards it as a mere alternation, but its great difference from any other of the rocks of the region, its surprising uniformity over long distances, both with and across the strike, in a region in which the alternations are as numerous as in this, as well as the fact that it widens rapidly southwestward, preserving all its characters, points to it as more than a mere stratum.

On the east side of the Schuylkill its visible width is not over two or three hundred feet. On Cobb's Creek it is nearly four miles. Its visible length is over eight miles; the southwesterly part much covered with soil.

On Cobb's Creek it is very well exposed. The southerly part is most porphyritic; in the central parts, and north of the centre, schists appear with characters of the Manayunk, and also of the Chestnut Hill series, while to the northwest the true porphyritic hard gneiss is well exposed about a quarter of a mile from the Chestnut Hill schists, near St. Denis Church, with no Manayunk schists visible intervening.

The hardness of this rock makes it everywhere prominent, and next to the Laurentian ridge, it is by far the most distinct formation of the region. While at the Schuylkill apparently monoclinal, and interstratified in the mica schists, I am disposed to regard it as an anticlinal, and at Cobb's Creek as two anticlinals, with an included synclinal of the schists. On each side of it, the schists exhibit certain peculiarities alike on both sides, and on the northwest side near Wynnewood, and on Cobb's Creek, it appears to dip beneath the schists.

In this porphyritic belt there is granite, unlike any other granite of the region. This granite is usually very coarse, composed of a flesh colored orthoclase and a peculiar chalk-white feldspar apparently not at all decomposed, but with very little lustre. It contains but little mica and quartz, much the larger part being the two feldspars, and it seems to be in small segregated masses in the schists rather than in beds or veins. Part of it is schistose. Sometimes it is a graphic granite, the structure developed by weathering and not conspicuous otherwise. Rarely it contains tourmaline, and no other mineral so far as I have observed, thus differing greatly from the granite of the Fairmount gneiss.

Some narrow bands of this gneiss are not porphyritic and are a very fine grained hard gneiss. Near Merion Station, Pennsylvania Railroad, one stratum closely resembles the helleflinta of Dannemora. In the old quarry at the Falls of Schuylkill, immediately west of the stone bridge of the Reading Railroad there was quarried a gneiss, somewhat resembling the Fairmount gneiss, but porphyritic, which the Fairmount gneiss is not. The Falls rock contains more feldspar and much less mica, and is much more compact.

In a quarry on the west bank of the Schuylkill, about a quarter of a mile above the Park bridge, at the Falls, a great variety of rock may be seen, and it is not certain whether this quarry is in the porphyritic belt, or in the Manayunk gneiss. There is much coarse granite like that of the porphyry, also highly feldspathic gneiss like that of the lower quarry, but some beds show the mica so abundant as to make a true mica schist, and the curved and twisted feldspathic layers hereafter referred to are found. In this quarry, pyrite and magnetopyrite occur with epidote which appears to be changing into hornblende.

On both sides of the porphyry, at the Schuylkill and west of it, the rocks are not essentially different. On the southeast they are somewhat softer and more evenly bedded and hornblende schist is more abundant, but in both there is the same evidence of folding and contortion, particularly exhibited by certain narrow feldspathic veins or beds, compressed sometimes to less than one-sixth their original length. So far as this region is concerned, this seems to be confined to the schists lying on each side of the porphyritic gneiss, and, on Cobb's creek, within it. It is in these schists that the serpentine rocks of Cresheim creek on the Wissahickon occur and also probably all, or nearly all, of the southerly Delaware county outcrops. While the Manayunk schists contain garnets they are not abundant, but often large.

There is one gneiss in Philadelphia which presents many points of difference from the other schists and gneisses of the region. This is the Frankford gneiss, best exposed at the quarries on Frankford creek. This gneiss is distinctly stratified. It contains comparatively little mica and hornblende, some specimens are strictly felsite and granulite. It is extremely hard and of even texture making excellent paving stone when properly broken for that purpose. Its granite veins, or more properly segregations, are chiefly orthoclase which contains at times Göthite in minute crystals ; muscovite occurs in the granite, but not in large quantities, also a highly lustrous black mica, which Prof. Lewis determined to be lepidomelane.[1] The gneiss is considerably jointed, and many of these joints are filled with stilbite in radiated crystallizations. Heulandite and apophyllite, the latter in very fine specimens, also occur in these joints.

Calcite occurs in small quantity apparently filling joint fissures, and in the calcite, fine crystals of epidote. Copper minerals occur, also molybdenite, at times abundantly, and sometimes in remarkably fine crystals showing the planes of the dome as well as the prismatic planes, perfectly bright and sharp. Sphene and uranium minerals occur, but the Autunnite so common in the Fairmount and Chester gneiss has not been detected, while sphene and molybdenite have not been found in the Fairmount gneiss.[2] The strike of this gneiss is nearly due west, and outcrops of it occur at Wayne station, Germantown, and at McKinney's quarry on the Wissahickon. The late Prof. H. Carvill Lewis regarded this gneiss as " a highly metamorphosed intrusive dyke of Lower Silurian age." [3]

There is another rather insignificant outcrop of a rock which does not fall within the description of any of the group, exposed on the Pennsylvania Railroad at 59th Street. It is chiefly a very compact felsite when not weathered, but some portions seem to be a mica schist. It is peculiar in containing a large percentage of pyrite, in some of the beds causing rapid disintegration on exposure, while others equally pyritiferous, but more compact, are perfectly stable. It apparently occupies a synclinal just southeast of the porphyritic gneiss, the axis of the synclinal pitches downward northeastward about thirty degrees.

The rocks of Rogers' second group, Mr. Hall's Chestnut Hill schists, are in certain areas very well marked, especially the garnetiferous variety, and that in which the wood-like structure is most developed, but there are areas difficult indeed to distinguish from the Manayunk schists. This may be well seen along the Wissahickon where the exposures are excellent yet no line can be drawn between the two, and in the Chestnut Hill schists, at Middleton's quarry, about

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[1] Proc. Min. and Geol. Sec. A. N. S. No. 1, p. 11.

[2] Molybdenite however occurs at Upland near Chester, perhaps in the Fairmount-Chester gneiss.

[3] Nature, Oct. 8, 1885, p. 560.

1000 feet northwest of Thorp's Lane and the steatite belt, is a bed of porphyritic granite, or granulite, clearly interstratified in the schists. Just below Thorp's Lane the peculiar contorted structure is well shown.

It is in these Chestnut Hill schists that the soapstone or steatite belt is found, and these rocks bound it on both sides, though at the Soapstone quarry on the northeast bank of the Schuylkill, at considerable depth, there was a hornblendic gneiss as the southeast wall, which, next to the steatite, passed gradually into chlorite.

It is to these schists that I understand Mr. Hall to believe[1] that all the serpentines of the district are confined (except the Cresheim Creek, the Flushing and the steatite of the northerly Radnor belt near Gulf Mills) and it is these which he continues along the line of the Pennsylvania Railroad from the Lafayette belt at Rosemont to the Radnor belt at Radnor station so as to include them both. But I have shown that this region is Laurentian and that schists are absent.[2]

Mr. Hall suggests that Mill creek may be the boundary between the Manayunk and Chestnut Hill schists, but it is remarkable that though Mill creek rises in these soft schists and the slopes of the Laurentian bordering them to the northwest, it crosses the border into the harder rocks and has cut through them a deep narrow valley to the river, close to, but S. E. of, the border line of the soft schists.

In the Chestnut Hill schists, west of the Schuylkill, are strata of white quartz becoming rusty on exposure. Seen occasionally in place, as on the Roberts road, and in the Railroad cut at Bryn Mawr, they are more frequently the only rock in the soil, and sometimes are very abundant, affording a guide to these schists, where they have decomposed out of sight, but not a certain guide, for in some places, as north of Morton, they seem to overlie the Manayunk schists. Perhaps the Chestnut Hill schists did overlie, and have been eroded, the hard quartzite only being left. This quartz occurs in large quantity at the narrow exposure of the schists in Marple.

Southwestward of the Schuylkill the divisions given above are not so distinct. The section on Cobb's Creek shows the porphyritic gneiss within a quarter of a mile of the soft garnetiferous schists, but here rocks, apparently of the Manayunk series, but much resembling some of the Chestnut Hill rocks, occur between outcrops of the porphyritic gneiss, all dips seeming to be northerly. Among the schists there are outcrops of a granite differing from that of the Fairmount gneiss as before described.

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[1] C^6 p. 3.

[2] 2nd Geol. Survey of Pa., An. Rep. 1888, Part iv, p. 1573.

Examining the section exposed along Darby creek, we find mica schists and gneisses of the Manayunk varieties, both feldspathic and hornblendic; indeed some of the hornblendic variety is almost entirely hornblende with a little quartz, or a diorite. The porphyritic gneiss occurs, and not far from it the soft mica schists, here in many of the beds, little more than granular quartz with a little mica forming whetstone, but in these occur beds of hard granitoid gneiss and of hornblendic gneiss.

Along Crum creek we find at Avondale an outcrop of the Fairmount gneiss well exposed by quarries, it being the most valuable building stone of this part of the State and at this point and on Ridley creek can be well seen the segregated masses of coarse granite which have here, as well as at Fairmount, yielded to mineralogists fine cabinet specimens of interesting minerals most of which are confined to this stratum.

Above this, near Swarthmore, is a considerable exposure of micaceous gneiss and mica schist, some of it very compact and hard and some of it containing garnet and andalusite. In this neighborhood occur also hornblendic schist and gneiss in considerable quantity. Northwest of this is the most westerly outcrop of the porphyritic gneiss of which the writer is aware. It is on the road leading north from Morton station one hundred yards north of the turnpike and about a mile from Morton. The strike is N. 10° W. dip 75° N. E. North of this are decomposed schists, with no good exposures. The strike near Trout Run was N. 10° E., the dip 30° to 60° S. E., and the schists were apparently of the Chestnut Hill group. Here, interbedded in the schists, are narrow beds of a syenitic gneiss which seems to be characteristic of this horizon. Rarely seen in place, it is found southeast of the Laurentian from the Schuylkill to Crum Creek strewn over the fields and along the roads, conspicuous by reason of the hornblende in it being very evident on the exposed surfaces as small crystalline masses, and by its invariably undecomposed condition. It occurs also northwest of the Laurentian in schists on the property of the late Moro Phillips, about half a mile from the Schuylkill on the southeastern side of Cream valley near Conshohocken. I have observed this rock in place in three localities only, that on Trout Run, on the Roberts road at the crossing of the old Lancaster road, and at Moro Phillips'. In none of these were the outcrops over two or three inches wide.

On Crum creek the porphyritic gneiss has not been observed nor the Chestnut Hill schists, though the latter may be under cover northwest of Palmer Mills. The visible rocks seem all to be of the Manayunk group.

Along Ridley creek the Fairmount gneisses are exposed and have been largely quarried. On the right bank near the road from Philadelphia to Chester there is a large quarry in hornblendic gneiss directly opposite (about one-eighth of a mile west of) two of the largest quarries in Fairmount gneiss. Above this are schists and gneisses similar to those along Crum Creek, except that north of Media, and also northwest of Media, enstatite appears in the schists. The softer Chestnut Hill schists with their garnets and ragged fracture are not to be recognized. It appears probable that they narrow in Marple township so as to occupy but two or three hundred feet, between the enstatite-serpentine near the Marple Barren Hill school house, and the antholite-serpentine to the southeast and that they then disappear. The exposures however are poor, and this is not certain.

Along Chester Creek, similar Manayunk schists and gneisses occur, but more massive, and harder, containing more feldspar, hornblende and quartz and less mica. From Bridgewater Station northward, hornblendic gneiss increases in quantity and the feldspathic gneisses become harder and more massive, but everywhere they are more or less schistose and distinctly stratified, and do not at all resemble the Laurentian of the Radnor-West Chester belt, which, with all its distinctive characters, is found within two miles of them east of Glen Mills.

Occasional hand specimens resemble some of the Laurentian, but in the field the differences are striking.

On the high ground adjacent to all these creeks the decomposition of the rocks has been so great that in comparatively few places can outcrops be observed. The mica schists and softer gneisses become a micaceous and kaolin-like earth. The hornblendic and harder feldspathic gneisses break up into schist-like pieces and these again, when containing much hornblende, into a very deep reddish-yellow soil, in which at moderate depths hornblendic fragments may be found.

Mr. Hall[1] thinks that what has been taken for the dip of the gneisses and schists in southern and southeastern Delaware County is cleavage, and that instead of their lying at high angles, they are not far from horizontal, overlying each other, the Philadelphia gneisses the lowest, the Manayunk schists the next, and the Chestnut Hill schists the highest. He places the serpentines, except those of Flushing and of Cresheim creek, all in one horizon and above the Chestnut Hill schists.

The hard hornblendic gneiss, as heretofore stated, he deems Laurentian underlying unconformably the other rocks and exposed by erosion along the streams. So far as my examination has gone, and I have examined many hundreds of outcrops, I have been unable to verify Mr. Hall's conclusions, and I believe the dips to be almost without exception at high angles generally towards the northwest, except along Chester Creek northward of Lenni, where the prevailing dip is southeast and less steep. Rejecting the segregated granitic veins often found, the distribution of the rock-making materials will be found not at low angles, but nearly vertical. Very evident is this when one of the many hornblendic beds occurs between micaceous and feldspathic rocks, but careful search has shown it in nearly every locality where the exposure was at all good. The want of uniformity in the various strata makes this all the more distinct. There is one exposure in Deshongs' quarry on Ridley creek, west of the Philadelphia and West Chester road at which mica schists appear to rest unconformably upon the Fairmount gneiss, but the exposure is far from good, and there is no other to my knowledge.

If Mr. Hall's theory is correct, we should find in ascending the hills from the creeks a decided change in the rocks; but, except that due to decomposition, no such change exists; on the summits, where exposed by road cuttings, the decomposed rocks are identical with those in the adjacent valleys. Besides this, the harder gneisses, both feldspathic and micaceous and hornblendic, which occur beyond all doubt interstratified in the mica schists, cannot be distinguished lithologically, from those of the areas about Chester creek colored Laurentian on the map in C^5. The peculiar weathering of the Laurentian is absent, there is no blue quartz, and there is no line of demarkation between the areas colored Laurentian, and those colored schists on Mr. Hall's map, beyond what would be easily and wholly accounted for by the greater hardness and want of decomposition of the rocks where deep erosion has taken place.

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[1] Second Geolog. Survey Pa., Vol. C^5 pp. 2 and 59, etc.

The question of the relative age of these rocks seems most difficult. Prof. Rogers' view is given as follows, p. 79:—

> "If we now review these interesting features in the structure of this broad zone of gneiss, we can hardly resist the conclusion, that in the three belts passed over by our section, there are really but two groups of rocks, a lower and a higher; that the entire zone, viewed broadly, constitutes but one wide synclinal wave or basin, the harder feldspathic and hornblendic gneiss dipping northward throughout the whole southern belt or outcrop and reappearing in steep and multiplied contortions on the other side of the trough, and compressed into the lesser foldings which it exhibits, by the lateral force of the wide crust undulation, within which it has been caught and folded."

That is, that the Fairmount and Manayunk gneisses formed the southeasterly leg of the synclinal, the Laurentian the northwesterly, with the Chestnut Hill schists overlying. Dr. T. Sterry Hunt refers to the identification of the rocks of Rogers' third belt with the Laurentian and, in his valuable contribution to American Geology published by the Second Geological Survey, Vol. E., seems to regard the Chestnut Hill schists as Huronian, the Manayunk and Fairmount gneiss and schists as Montalban overlying them, and in these views the lamented Prof. Lewis who made considerable study of these rocks is well known to have coincided,[1] though later[2] he concludes that they are of purely eruptive origin, that a re-crystallization of the old material under the influence of pressure-fluxion has taken place, by which the feldspar has been re-crystallized, the biotite made out of the hornblende, garnets have been developed and the quartz granulated and optically distorted by the pressure.

Dr. Hunt's description of the Montalban as given in Min. Physiology and Physiography, p. 411, will be found to accord in every particular except the "dichroite gneiss and crystalline limestone," with the rocks described in the Manayunk and Chestnut Hill groups. It is as follows:—

"As regards this younger gneissic or Montalban series in North America, it need here only be said that it contains fine-grained white gneisses, sometimes porphyritic, but distinct from the granitoid gneisses of the Laurentian, and passing into granulites, on the one hand, and into very quartzose coarse-grained mica schists, on the other. It also includes hornblendic gneisses and black hornblende schists, together with serpentine chrysolite rocks, dichroite-gneiss and crystalline limestone. The mica schists of the series often contain garnets, staurolite, andalusite, fibrolite and cyanite, while in the granitic veins which traverse the series are found tourmaline beryl and cassiterite. The total thickness of the Montalban is apparently much greater than that assigned to the Huronian, upon which it sometimes rests unconformably, or in the absence of the Huronian, as is often the case, directly upon the Laurentian."

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[1] Geol. of Phila., a lecture before the Franklin Inst., Jan. 12, 1882, p. 18.

[2] Proc. British Assn. in Nature, Oct. 1st, 1885, p. 560.

Mr. Hall's views have already been given, viz., that the Philadelphia gneisses are the lowest except the Laurentian, the Manayunk, schists next, the Chestnut Hill schists above and the serpentines the highest.[1] He further states:—

"I think there is no possibility of assigning the rocks of the Philadelphia Manayunk and Chestnut Hill groups (the First and Second belts of Prof. Rogers) to any place below the slates of the South Valley Hill or Hudson River groups. But to what horizon in the palaeozoic column they belong must remain for the present uncertain." C^6 p. 9.

This generalization is derived chiefly from the finding of Potsdam and No. 2 Limestone between the Laurentian and the schists. Prof. Lewis described itacolumite southeast of the Laurentian, east of the Schuylkill and the writer found a similar rock west of the Schuylkill.[2] Mr. Hall's observation has been doubted, but it would seem without reason except that he gave no exact locality to enable others to confirm his observation. A full description may therefore be of interest.

Passing southeastward along the North Pennsylvania Railroad from Edge Hill Station, we pass through the well-known deep cut through the Potsdam of the Barren Hill belt. We then pass for a mile through a valley, and then come to the garnetiferous schists of the Chestnut Hill belt at Jenkintown.

In this valley, a mile northeastward of the railroad, Laurentian is abundant in the form of large masses on the surface. Southwestward, high ground is soon reached on which the fields are full of Laurentian fragments. About .6 miles W. 5° S. of Glenside station is a wood in which is a small quarry exposing about 50 feet vertically of Laurentian rocks, some N. 30° E. dipping 55° N. W. in the southeasterly part of the quarry. In the northwesterly part the rock is much jointed, the joints irregular.

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[1] C^5 pp. 2, 59, etc.

[2] 2nd. Geol. Survey of Pa., An. Rep. 1886, Part IV, p. 1595.

W. 20° S. .4 miles from Glenside, on the east side of the Limekiln Pike, the Potsdam is best exposed. This is in a quarry about a hundred yards south of the Waverly road, but the same belt is conspicuously exposed on the Waverly road southeast and southwest of the pike, the Waverly road changing its direction from northwest to southwest at the pike and hence crossing the belt twice. The Potsdam here makes a ridge or hill, known as Waverly Heights, southeastward of the Laurentian hill. In the quarry it looks exceedingly like that in the quarries to the northwest (Barren Hill belt) except that the bedding is less regular, the quartz more cherty, and the rock harder. In the quarry the strike was N. 80° E. dip 70° S. E., on the road southeast N. 70° E. dip S. E., and on the road southwest N. 65° E. 70°–80° S. E. Southeast of this no exposures were seen, but there were schistose fragments. The strike of the Potsdam carries it into the bold hill to the northwest, the southeast hill of the Whitemarsh or Montgomery valley, Potsdam entirely at Edge Hill, but further southwest covered with Laurentian fragments and continuing (of schists) to form Chestnut Hill. The soil seems deep, and no exposures were observed. One mass of Bryn Mawr gravel was seen.

On the Paper Mill road, which skirts the hill on the northwest, southwest of the road which southeastward forms the northeast line of Philadelphia, the ground is low until within a half mile of the turnpike. Here is a spur of Chestnut Hill, and on the road cutting at the summit is Laurentian, poorly exposed, consisting of one large mass, and eight smaller, all having exactly the same strike about N. 35° E., and therefore I believe in place. 200–300 feet S. W. is Potsdam abundant, striking N. 80° E.; following this, are schists interbedded apparently with Potsdam; mostly soft and decomposed but showing the same strike and probably a steep easterly dip.

These schists resemble very strongly the schists southeast of the Laurentian west of the Schuylkill which include a white rock closely resembling the Potsdam.

I believe this to be an unconformable contact between the Laurentian and the Potsdam and that the schists immediately southeast of the Laurentian are Potsdam.

It is, of course, possible that these schists are more recent than the Potsdam, and formed from its debris, but the evidence seems very strong that here at least they are not older.

These schists continue about one-eighth of a mile to low ground and a creek, southwest of which schists resembling the spangled mica schist occur, and continue, poorly exposed, to the turnpike. The strike of a bed of hard gneiss in the schist is N. 85° E. Here the Paper Mill road ends, though shown on maps to continue. In fact Thorp's Lane about .1 mile northwest continues to the Wissahickon. On this, schists are seen with a strike N. 65° E. and soon the steatite and serpentine N. 55° E. The road is nearly on this strike but a little more southerly, so that near the creek it lies to the southeast of the steatite which here appears to be synclinal, the schists to the southeast regularly bedded dipping N. 40° W. 50° while the serpentine rocks on the northwest side dip slightly S. E. The schists to the northwest are about vertical. Here, as at the North Pennsylvania Railroad, there has been an ancient gap in the Laurentian ridge which further southwest appears as a very bold hill united with the schistose hill at the Ridge turnpike, but toward the Schuylkill separated from the schists by a valley in which the Lafayette serpentine makes its appearance at its extreme northeast outcrop.

If we study the rocks of Cream Valley, the corresponding rocks on the northwest side of the Laurentian anticlinal, we find evidence that the schists there are in connection with the Potsdam.

In this narrow valley we find garnetiferous schists strongly resembling some of those southeast of the Laurentian. Close to these, but beyond them, is Potsdam, beyond it Rogers' altered primal, and limestone. All seem to be conformable, and the schists and the Potsdam appear at one locality northeast of Wayne to be interstratified. The exposures are very poor.

The altered primal includes pebbles of Laurentian, some of large size.

The Radnor serpentine appears to lie between the Laurentian and these schists, and the northerly belt of steatite to lie in the schists, similar to the relation southeast of the Laurentian, except that on the S. E. there is a thin bed of spangled mica schists bearing very strong resemblance to the mica schists of Cream Valley, between the Laurentian and the serpentine. There is a connecting link between the schists and the altered Primal of Rogers in peculiar nodules, looking like pebbles, usually of a vitreous semi-transparent colorless feldspar with perfect cleavage, apparently orthoclase. While not uncommon they are not abundant in the rock. The garnets are confined to the mica schists but much of the schist is not garnetiferous. This is the same schist that is found with the limestone northwest of West Chester (Cope's), as it may be traced almost continuously along the southerly edge of the South (Chester) Valley Hill.

THE SERPENTINES.

The serpentines of these areas may be conveniently arranged with reference to the Laurentian axis above referred to. So arranged, except the first, and in a general direction from northeast to southwest they are as follows:

A. The serpentine and steatite of the southeast slope of Chestnut Hill (Laurentian) north of Easton, Pennsylvania.

B. The great Radnor belt, lying on the northwest of the Laurentian, including the belt north of West Chester, with which it is apparently identical and almost continuous.

C. The La Fayette belt, lying on the southeast of the Laurentian, including the outcrops from northeast of the Schuylkill, southwestward through Lower Merion, southerly Radnor, southeasterly Newtown and the southwestwardly part of Marple township, and the outcrop at Blue Hill.

D. The outcrop, in the western part of Newtown township, and in the easterly part of Edgemont, including Castle Rock.

E. The outcrops at Willistown, Chester county, extending a short distance into the northerly part of Edgemont, Delaware county.

F. The soapstone quarry, or steatite belt extending from Chestnut Hill, Philadelphia, to a point about three-quarters of a mile northeast of Bryn Mawr nearly parallel to, and about a half mile southeast of, the LaFayette belt (C).

G. The northerly Radnor belt, nearly parallel to the northeasterly part of the great Radnor belt (B) and about a thousand feet northwest of it.

H. The outcrop on the Wissahickon near the mouth of Cresheim creek, southeast of Chestnut Hill, and certain small areas in Marple and Upper Providence, southwest of the large Marple outcrop.

I. The numerous adjacent outcrops in Middletown Township west of Media.

K. Certain small areas south and southwest of the Media outcrop, and the outcrops near Glen Mills on Chester creek.

These serpentines have been studied by many geologists but the conclusions reached have not been uniform. The following extracts from the reports of the Second Geological Survey of Pennsylvania will show some of these conclusions. I have added to each the letter indicating the outcrop referred to in the list above given.

C^4 p. 84 (B). "The southern edge of the South Valley hill belt of talc mica slates is defined upon the map, by a chain of dots and stripes of two colors representing outcrops of serpentine and outcrops of crystalline limestone.

Were these outcrops ranged in more than one line [1] the task of explaining their appearance at the surface would be much easier. But a *single line* of them necessarily places them either at the top or at the bottom of the talc-mica schist formation; Mr. Hall choosing the former, Mr. Rogers the latter alternative.

The case is complicated by the fact that the outcrops along this one line are sometimes serpentine, sometimes limestone. It looks as if the serpentine might be a subsequent modification of the limestone; or else that one and the same original magnesian sediment was heavily charged with carbonate of lime in some places, and was a non-calcareous silicious mud in others."

C^4 p. 85 (B). "The subject is crowded with embarrassment; and all the more seeing that the serpentine-limestone range along the south edge of the talc-mica belt ought to hold some discoverable relation with other ranges of serpentine crossing Delaware, Chester and Lancaster counties; as well as with the famous serpentine outcrop between limestone and gneiss on the Delaware river, north of Easton, in Northampton county." (A.) See Report D^3, 1882.

C^4 p. 85 (A). "The fact that the Northampton county serpentine underlies the Great Valley limestone formation in connection with Potsdam sandstone supports Mr. Rogers' views in Chester county, and strongly opposes Mr. Hall's conjecture that the Chester serpentine may be Upper Silurian. On the other hand the fine serpentine outcrops on Lake Memphremagog, at the Canada Vermont line, are clearly Upper Silurian, but they are far removed from any gneissic region. Mr. Hall after examining the Easton serpentines, considered them altered calcareous slates lying at the base of the limestone formation, over the Potsdam sandstone." (Foot note.)

C^4 p. 87 (B). "It is evident that even a synclinal belt of serpentine 2,000 feet wide, or even 400 feet wide, can mean nothing else than a great thickness of the talc-mica schist formation metamorphosed more or less completely into serpentine. And a good cause for such alteration is present in an extensive outburst of *trap* close by; and everybody familiar with the surface of Delaware and Chester counties knows how almost invariably its trap and serpentine appear together.[2] This of itself effectually divorces the serpentine outcrops of Chester county from the limestones."

C^6 p. 26 (F). "The southern belt of serpentine extends from Chestnut Hill tothe Delaware county line, crossing the Schuylkill river below Lafayette station. It has not been proven to be a continuous belt; and the color indicates the steatite or serpentine where its existence is beyond dispute. This range or belt of serpentine belongs, undoubtedly, to one horizon, although the deposits may be in lenticular masses.

C^6 p. 26 (C). "The northern belt of serpentine extends from a point a short distance east of the Schuylkill river to the neighborhood of the Delaware county line, north of Bryn Mawr. This belt seems to be a repetition of the southern belt, being on the north side of a synclinal basin.

East of the Schuylkill the extent of the outcrop is not definitely known. The outcrops designated are the only ones positively known to exist. If there was no faulting along the northern edge of the belt, between the Schuylkill and Chestnut

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[1] In Radnor Township they are in two lines. T. D. R.

[2] My observations do not confirm this. Proc. Acad. Nat. Sci. 1883, p. 241.

Hill, the northern and southern belts ought to join at the eastern end of the synclinal basin; but they apparently do not."

C^5 p. 15. "The serpentine and associated rocks lie in synclinal basins. This is the rule in regard to all serpentine areas in Delaware county and probably with most of the serpentine in this district."

C^5 p. 57 (C & I). "The serpentine crosses the northern portions of the township (Upper Providence) in two belts which indicate shallow synclinal basins and the erosion between these areas or basins exposes the underlying mica schists."

C^5 p. 13. "The Delaware county deposits demonstrate the fact that the serpentine areas are shallow synclinal basins, many of them saucer-shaped."

C^5 p. 13 (G). "There is a small area of steatite close to Gulf creek and near a limestone deposit. I think that there is no question that the steatite belongs to the same horizon as the serpentine. The belt of serpentine" (B) "which makes its appearance in Radnor township belongs geologically to the serpentine belt which extends across the Schuylkill river and through Lower Merion township, Montgomery county" (C), "and is a direct continuation of the belt which passes through the corner of Tredyffrin township, Chester county, and passes north of West Chester" (B).

"The serpentines throughout the central portion of Delaware county" (I. K. L.) "belong to the same horizon as those in Lower Merion Township, Montgomery county" (C. F. G.).

From the above facts it will readily be seen that all the serpentines through this region belong to the same geological horizon."

C^5 p. 14. "It is safe to assume that the serpentines are one of the most recent deposits."

C^5 p. 65 (K). Middletown Township. "There are numerous small areas of steatite, anthophyllite, and actinolite, indicative of the serpentine horizon, through the southern and southwestern portion of the township but these rocks seem to be confined to very small areas lying upon the schists and gneisses which are exposed in the escarpments."

C^5 p. 64 (I). "Light feldspathic granite is formed in this township (Middletown) associated with the serpentines."

"The geological position of this granite is below the serpentines."

The term "talc mica" is applied above to the hydromica schists of the South (Chester) Valley Hill, sometimes called chlorite schists. In fact they contain neither talc nor chlorite unless in very minute quantity.

Upon studying the relation of these serpentines to the adjacent rocks the fact is at once apparent that most of these outcrops, and those most extensive, occur along the margin of the Laurentian rocks, and very close to that margin, while some of them, generally small in area, seem with equal certainty to be some distance from the Laurentian, and to have no connection with it.

To the former belong:

A. Easton. *B*. Radnor—West Chester. *C*. LaFayette. *D*. Southwest of Newtown. *E*. Willistown.

And to the latter:

F. Steatite. *G*. Northerly Radnor. *H*. Cresheim Creek. *H*. Southeast of Marple schoolhouse. *K*. Southwest of Media.

And probably *I*. West of Media.

The Media outcrop as delineated on Mr. Hall's map would be nearly continuous on its northwestern edge with the Blue Hill outcrop of the LaFayette belt and on its southwestern with the outcrops southeast of the great Marple outcrop.

This region is much covered with soil and it may be possible that the two parallel belts exist with a schist area between. The results of a careful examination of this outcrop are given hereafter.

The close connection of one series of these serpentine areas with the margin of the Laurentian being apparent, it would seem that the serpentine at Chestnut Hill on the Delaware, one mile north of Easton should afford us a key, the exposures there being much greater and better than any in Delaware or Chester County. As to these in addition to the quotations above given the Second Geological Survey states as follows:

D^3 p. 252 (A). "Along the southern escarpment of Chestnut Hill steatite and serpentine extend from the Delaware river to a point about one-half mile west of Bushkill creek. The belt has a width of about four hundred feet.

The serpentine and steatite have generally a greenish color; associated with the steatite massive, coarse quartzose feldspathic rock (granulite) occurs.

The rock is different in character from the feldspathic rocks of the gneissic belt which form the mass of Chestnut Hill. The feldspathic rock associated with the steatite belongs evidently to the steatite belt."

D^3 p. 256 (A). "On the southern slope of Chestnut Hill the Upper Primal slates (hydro-mica slates) appear to have been altered into steatite and serpentine (§251). No limonite occurs on the flanks of Chestnut Hill."

D^3 p. 253. "The steatite and serpentines of this belt appear to be equivalent to the slates overlying the Potsdam sandstone. (Upper Primal Slates.) I see no explanation for the alteration of the hydro-mica slates of the Upper Primal into steatite and serpentine in this locality." (Rogers, p. 94–5.)

D^3 p. 58. "Whether the serpentine and other magnesian minerals found at the base of the formation along the south flank of Chestnut Hill, north of Easton, belong to this formation" (Chazy and Calciferous Limestone) "or not is still an open question."

Visits to the locality forced me to a conclusion differing from the above. Passing up the west bank of the Delaware from Easton the limestone appears for a distance of nearly a mile dipping southeastwardly 60° to 80° then 200 feet are under cover, and then a narrow bed of steatite appears. The southeast wall is not visible, the northwest wall is Laurentian and were this the only exposure there might be no reason to question the conclusion that the steatite is an altered slate between the Laurentian and the limestone.

East of this quarry may be seen Laurentian in place and the contact with the talc schist may be seen.

Immediately north of it is another quarry apparently within the Laurentian, and here may be seen masses of tons weight having all the appearance of Laurentian but converted in part or in whole into talc.

One mass, five or six feet long, was nearly pure talc schist at one end, while at the other, much quartz remained and to the eye the rock looked like unaltered Laurentian.[1]

Northwestward of this quarry all visible rocks are Laurentian for about two hundred feet to a quarry of similar talcose rock quarried on a slope up and into the hill somewhat over one hundred feet. The quarry when visited had not been wrought for some time and large masses of the south wall had fallen in. These masses were Laurentian, the north wall was the same. Some of the fallen masses showed a change from syenite, or more strictly granulite, into steatite.

Northwestward from this, the Laurentian was apparent for three hundred to four hundred feet, where another and much larger outcrop of steatite is quarried. The contacts here were not visible.

Northwestward from this followed two hundred to three hundred feet of Laurentian including one very prominent overhanging cliff and then another exposure of steatite, in which was a considerable quarry. Northwestward of this the Laurentian again appeared. The dips were not clear but from what could be observed are not far from vertical. The hill adjacent to these quarries probably exceeds four hundred feet in height. It seems incredible that these four outcrops are an overlying stratum in three successive compressed synclinals. It is much more rational to conclude that they are interbedded in the Laurentian.

On the Bushkill, which cuts the same hill about one and a half miles from the Delaware the outcrop is not so distinct but here also the steatite and serpentine are between walls of Laurentian, and in these hard unaltered Laurentian rocks may occasionally be found masses of rock apparently changing into steatite and serpentine.

Dr. Hunt in his Mineral Physiology and Physiography seems to regard the change of gneiss into serpentine or steatite as almost an absurdity, and before visiting this locality I should have agreed with him, but here we certainly have Laurentian gneiss changing into steatite, or steatite changing into Laurentian gneiss.

Considering the Delaware, Chester and Montgomery county serpentines in detail we find as follows:

At the northeastern end of the Radnor–West Chester belt there is Laurentian on the strike line, and on both sides of the belt, but the exposure does not show the walls in place. About a quarter of a mile northwest is garnetiferous mica schist in place, and one hundred yards further northwest Potsdam sandstone.

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[1] A piece of this is in the collection of the Academy.

At the outcrop northwest of Radnor station garnetiferous schist and gneiss were disclosed in a well not over two hundred feet north of the serpentine. In the strike line (southwest) and to the southeast Laurentian fragments abound. About five hundred feet northeast of the northeast end of this exposure runs the Radnor and King of Prussia road. On this, to the northwest of the line of strike is an outcrop of Laurentian in place, while to the southeast and very close to the strike line is a very hard porphyritic contorted mica schist unlike any other outcrop of the region.

Further west, between Radnor and West Chester, the serpentine is much concealed, but there are some outcrops of interest.

The most important of these lie a little less than a mile south of the Pennsylvania Railroad, near Paoli, Green Tree and Malvern stations and among the headwaters of Crum creek. Southeast the Laurentian is apparent, here and there in conspicuous outcrops. On the road leading to Malvern, we find, going north northwest, as follows:

	feet.
LAURENTIAN.	
Low ground,	100
Serpentine,	250
Low,	50
Garnet staurolite schist,	100
Low,	500
Garnet staurolite schist,	100
Trap,	50
Garnet staurolite schist,	200
Serpentine,	400
Low,	300
Garnet staurolite schist,	200
Concealed,	300
Hydromica schist of the South (Chester) Valley Hill,	5000

Showing here two distinct outcrops of the serpentine, with mica schist between them, and beyond the northernmost.

About half a mile east of the Malvern road is a nearly parallel road leading to Green Tree. On a road connecting the two, just south of the serpentine, Laurentian is conspicuous. Going N. N. W. on the Green Tree road, the belt is again divided, the southerly outcrop being close to where the two branches of Crum creek unite, the northerly just below where the road turns abruptly E. N. E., and exposed more conspicuously at a quarry an eighth of a mile W. S. W. of the bend. Here white quartz is abundant, much like that which abounds at certain places in the mica schists southeast of the LaFayette belt, and the garnetiferous schist is visible in the E. N. E. part of the road. About a quarter of a mile east of the Green Tree road is another road leading also to Green Tree and joining the former road where the east northeast direction changes to north northwest. Two small branches of Crum creek cross this road, and unite just below it. Southeast of the east one there is serpentine which extends about sixty feet beyond the northwest side of the creek. The ground is then low to the west branch, beyond which is an area of serpentine probably eight hundred feet wide, but it appears to end very abruptly, for on the line of strike the road mentioned just previously to this is not over six hundred feet distant, and in it mica schists appear, while the serpentine is to be found only by careful search. On the strike line northeasterly (N. 35° to 52° E. wherever it can be observed) the serpentine outcrops are extensive but their margins are all concealed.

Immediately southeast of the serpentine just mentioned southeast of the east branch of Crum creek, a road runs to Paoli, in a direction nearly northeast. Going northeast we find serpentine followed by fragments of loose trap, fragments of garnet-staurolite schist, then serpentine, trap, serpentine, trap, garnetiferous schist and finally hydromica schist.

While it is impossible to fix the boundaries of these rocks with any accuracy, there can be no doubt that we have here an area of the garnetiferous schists included within serpentine areas and bordering the northernmost on the north. This schist appears nowhere on the south unless at one point in the road last mentioned southeast of the east branch of Crum creek, but the outcrop is merely of loose rock and garnets in very small quantity and may not be actually in place.

All observed dips in the serpentine were northwest 60° to 90°, but few dips seemed trustworthy and in the schists no exposures whatever giving trustworthy dips were found.

Within a quarter of a mile of the northwesterly margin of the serpentine and garnetiferous schists are the hydromica schists of the South (Chester) Valley Hill very readily distinguishable from the garnetiferous schists, and throughout the whole distance Laurentian rocks are found close on the southeast.

North and northwest of West Chester Laurentian also appears close to the serpentine on the southeast side, while in many places on the northwest side fragments of garnetiferous schists and loose garnets are found in the soil with occasionally staurolite.

About a mile and a quarter N. N. W. of West Chester, the bold serpentine ridge ends abruptly, the mica schist fragments appearing in its line of strike, here S. 45° W. with an unusually uniform dip in the serpentine about 45° S. E., or toward the Laurentian. The Laurentian is not sufficiently exposed to give its dip, but the strike seems to be about the same as that of the serpentine.

Southwest of this is a small outcrop of serpentine, a little south of the line of the strike of the former, and beyond are outcrops nearly five hundred feet apart to the northwest and southeast of a stream and low ground, evidencing a wide outcrop or two narrow ones. Northwest of the serpentine is garnetiferous schist.

Southwest of this outcrop is a ridge geographically the continuation of the serpentine ridge, but apparently of Laurentian rocks, not visible in place, but abundant as loose masses, but on the road southeast of this hill garnetiferous schists with staurolite are exposed. The great mass of the Laurentian lies still further southeast, so that if the ridge is Laurentian, we have an included valley of the schists. No serpentine is visible. The ridge ends at the road from West Chester to Downingtown. At the time of my visit an alteration of this road had caused a cut to be made making a cross-section of the end of this ridge, showing to the southeastward Laurentian, dipping northwestwardly about 22,° overlying which was a bed of slaty steatite, or impure talc schist, and overlying this, mica schist and quartz, much contorted, the lowest part dipping conformably with the steatite and Laurentian, the upper so contorted that no structure was apparent. To the northwestward the Laurentian appeared dipping southeastwardly about 30° the middle being occupied by the mica schists but no steatite or talc appearing to the north. The exposure is probably two hundred feet wide. The rock which I have termed Laurentian at this exposure I believe to be such, but it is not so characteristic as to be beyond doubt.

Further southwest on the line of this hill, after 400 to 500 feet of low ground, is another hill which contains two outcrops of limestone (Caleb Cope's). The southerly one has been excavated some two hundred feet into the hill, exhibiting a stratum of crystalline limestone probably 60 feet wide bounded on the northwest by garnetiferous mica schists, with feldspar nodules, most closely resembling those of Cream Valley, Radnor. On the southeast is a rock closely resembling the Laurentian, containing interbedded limestone. This is not far north of undoubted Laurentian, and is either that rock, or as Dr. Frazer has suggested,[1] a more recent formation made up of the fragments of the underlying rocks. In this quarry a satisfactory exposure gave strike N. 40° E. dip 55° S. E. Northwest of this outcrop are 100 feet of the schists, and then a very small exposure of saccharoidal limestone, apparently an anticlinal in the schists. The steatite outcrop is 450 feet N. 50° E. from the southerly limestone, N. 65° E. from the northerly.

A short distance northwest are the hydromica schists of the South (Chester) Valley Hill.

Dr. Frazer[2] thinks it probable that the serpentine of this belt is a metasomatized portion of the hydromica schists with which he regards it as lying in contact; but towards the northeast we find between the hydromica and this serpentine, limestone, Rogers' altered primal, garnetiferous mica schists, Potsdam sandstone and steatite, the garnetiferous mica schists much more nearly continuous (apparently) than the serpentine. North of Radnor station fully a thousand feet of the above rocks intervene between the hydromica schists and the serpentine. I have nowhere seen the hydromica schists of the South Valley Hill in contact with the serpentine.

THE LAFAYETTE BELT.

On the southeast side of the Laurentian anticlinal is the LaFayette belt, but along nearly its whole course there intervenes visibly between it and the Laurentian a schistose rock, including crystals of mica like the feldspar crystals in a porphyry and more rarely visible a thin bedded gneiss resembling the altered primal of Rogers so largely exposed on the northwest side of the anticlinal. The schist is very uniform and persistent but it is nowhere well exposed. At times, as on the southwest bank of Meadow Brook north of

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[1] C 4 p. 294.

[2] "These results seem to lend a high degree of probability to the theory that at least this belt (Radnor West Chester) is a metasomatized product of a layer or layers of the hydromica schists in contact with which it lies and with which its relations are abundantly made out by very different processes of comparison. viz., stratigraphically, geographically and chemically." Trans. Am. Inst. M. E. Troy Meeting, Oct. 1883.

Roberts' road a mile and a half south of the old Lancaster road, and also on the Coopertown road (or Roberts' road as they run together) west of the bridge over Darby creek, it becomes a coarse granite or porphyry, containing, however, but little quartz. Some portions exactly resemble part of the garnetiferous schist, northwest of the Laurentian, but I have nowhere observed garnets in it, though a loose fragment of rock found on the Roberts road near Meadow brook contained staurolite.

The rock in contact with the LaFayette belt on its southeastern margin is rarely visible at the point of contact. It may however be seen at Rose's quarry, and also on the Roberts road east of Meadow brook. It is a fine-grained mica schist, not contorted, not wood-like in its fracture, like that near the steatite belt to the southeast. It occasionally contains garnets but it is not distinctly garnetiferous like that further southeast.

It contains strata of schistose hornblende rock which, at one locality 200 feet north of the West Chester and Philadelphia road, a mile east of Newtown Square near the south line of Newtown Township, appears to be changing into serpentine and these hornblende rocks are quite persistent, being found as far southwest as the Willistown outcrop.

The best exposure of this belt is at Rose's quarry near the Schuylkill. Here the dip is 45° to 55° S. 30° to 40° E. and beds of serpentine above may be traced into enstatite below. Southwest are large masses of enstatite in great quantity. This is also the case at the outcrops on Darby creek and in Marple. Chromite was mined near Darby creek in this belt. (Moro Phillips Chrome Mine.)

The LaFayette belt may be traced by distinct outcrops from a point about half a mile north of the Schuylkill to Rosemont station P. R. R. Southwest of Rosemont, the outcrops are more indistinct but careful search will disclose them between the old Lancaster road and the Radnor and Chester road; on this road a wide outcrop suddenly appears and continues (except at Darby creek where some low ground intervenes, beneath which it is doubtless concealed) to the Philadelphia and West Chester road about a mile and a half east of Newtown Square. Beyond this for a short distance it becomes inconspicuous or absent, but the ground is level and there are no good exposures of any kind. About half a mile further southwest it is again exposed as the great Marple outcrop, about a mile and a half northwest of Palmer's Mill on Crum creek.

Southwest of this, the next exposure of the serpentine which I have seen is at Blue Hill between Crum and Ridley creeks. This outcrop lies near Sycamore or Bishop's Mills on Ridley creek and nearly in the strike of the LaFayette belt. The Marple outcrop lies south of this line, probably indicating a curve in the Laurentian, but the adjacent rocks on the northwest are not visible in place at Marple. The elevation of the region immediately northwest is indicative of the Laurentian. At Blue Hill the Laurentian again seems to almost surround the serpentine. Just north of the school-house the Laurentian appears in place with a strike nearly south, immediately west of abundant fragments of honeycomb quartz perhaps indicative of underlying serpentine, and not over 300 feet northwest of abundant serpentine in place. Further northeast the Laurentian occupies the entire hill, which here is quite elevated, with steep slopes on the northwest and southeast, and a more gentle one on the northeast to Crum creek.

In the serpentine where it has been quarried on the Providence road opposite the Blue Hill school-house is a small quantity of granulite apparently a dyke. On the road along the creek south of the serpentine a decomposed granite or granulite appears, the indications being quantities of small masses of crystalline feldspar.

The locality southwest of Newtown Square is not well exposed. Laurentian, unaltered, may be seen at the fork of the roads three-quarters of a mile west of Newtown Square and its strike would bring it northwest of, but very close to, the serpentine. The Castle Rock enstatite seems to be continuous with this serpentine, separated from it only by Crum creek and the immediately adjacent low ground. This locality is not far from the Willistown exposure next described and is probably identical with it.

The Willistown outcrop, like that northeast of Radnor station, appears to be largely within the Laurentian, which extends from West Chester eastward as close to it as any rock can be observed. To the northward Laurentian is everywhere. Following the serpentine table land eastward, the serpentine fragments in the soil suddenly, within less than 100 feet, are replaced by hornblende fragments and, a short distance beyond, Laurentian rocks form a steep bluff. This bluff rises precipitously from the north branch of Ridley creek on the east, and from the Philadelphia and West Chester road on the north. The Laurentian dips S. 25° E. 65°. The rocks are partially exposed along the road and going west are as follows:

First. Laurentian.

Second. A porphyritic gneiss resembling Rogers' altered primal as found northwest of the Laurentian.

Third. A micaceous schist in very small quantity.

Fourth. Hornblende fragments.

Fifth. Serpentine.

The serpentine extends along the road several hundred feet. North of it is Laurentian, but no contacts are visible. About a quarter of a mile west of it appears the same rock spoken of as resembling Rogers' altered primal, striking, like the former, N. 65° to 70° E. but the dip not certain. Beyond this west to West Chester and north for several miles the whole region is Laurentian.

It will be seen that all these outcrops of serpentine are close to the margin of the Laurentian, two of them at least within its margin, though there is no sufficient evidence to prove whether they are of that age or more recent.

Mr. Hall, as before stated, thinks it safe to assume that they are among the most recent deposits, but the section of the Radnor belt shows going northward from the Laurentian axis several rocks between the serpentine and the Potsdam sandstone, seeming to indicate that here at least the serpentine is the oldest except the Laurentian, and that the steatite is more recent than the serpentine but below the Potsdam, unless in a synclinal.

On the southeast side of the Laurentian the existence of the Potsdam is not certain where the serpentine occurs, but as above stated it does occur at Waverly Heights in Montgomery county, between the Laurentian on the northwest and the schists on the southeast and there are in Radnor and Lower Merion certain rocks in the same relative position which closely resemble Potsdam. If this is Potsdam then the serpentine is again between the Laurentian and the Potsdam, but the very position of the serpentine, so very close to the Laurentian, would indicate that it was an older rock than the mica schists to the southward.

We come now to the consideration of the outcrops which are not near the Laurentian. Of these perhaps the most important are the steatite belts N. W. & S. E. of the Radnor and LaFayette serpentines.

THE NORTHERLY RADNOR BELT.

Outcrops of this belt lie nearly parallel to the great Radnor belt but extend a mile further northeast and all lie within a lineal distance of about two miles, ending about three-quarters of a mile southwest of the northeast end of the Radnor belt, bearing precisely the same relation to it and to the Laurentian axis as does the steatite of the better known Soapstone quarry belt to the LaFayette belt. The exposure of the northerly belt is poor, but it is of no little interest on account of its similarity to the soapstone quarry belt and to the fact that along its line occur garnetiferous schists followed by Potsdam sandstone and limestone. A trench dug for water pipe on the property of Judge Hare about a mile northeast of Radnor Station afforded a tolerable section. The trench was about N. 75° W. while the strike of the belt is probably N. 60° E.; the distances given are corrected so as to approximate the dip line.

Foot of hill E. 40 feet	Mica schist, decomposing steatite with numerous cavities filled with ferric oxide exactly resembling that of the soapstone quarry below LaFayette where the ochre is due to weathering of Breunnerite. With this was chlorite schist.
90 feet	Slaty serpentine.
200 “	Hard serpentine.
300 “	Talc schists and hard serpentine.
350 “	Rogers’ altered primal.
375 “	Mica schist.
425 “ W.	Rogers’ altered primal.

A half mile southeast of the LaFayette belt, lies the steatite belt, in which quarries for soapstone have been wrought for over a century. The LaFayette belt appears to end northeastwardly in a small valley of an affluent of the Schuylkill, not far from the river. The steatite belt however extends further northeast, and crosses the Wissahickon near Chestnut Hill, Philadelphia, ending in the schists of Chestnut Hill, near Thorp’s lane a short distance southwest of the turnpike.

This is another, but probably purely accidental resemblance between the two belts, both being much shorter, but beginning much more northeastwardly than the corresponding parallel serpentine belt.

The characteristic of this belt is a steatite including masses of very hard black serpentine. These have resisted erosion and sometimes appear along the outcrop like huge boulders, some of them, near the soapstone quarry, being separate and of many tons’ weight. Some of the black masses are pseudomorphs after staurolite.[1]

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[1] Proc. Acad. Nat. Sci. Nov. 21st, 1871.

Prof. Rogers, whose plutonic views as to most of the serpentines are well known, recognized this belt to be an altered schist though he regarded it as "metamorphosed by infusion of magnesian matter from the dyke of intrusive serpentine which everywhere adjoins it."[1] But it is this "intrusive serpentine" which contains the pseudomorphs after staurolite.

This belt has afforded more minerals than any other serpentine of the region, except, probably, Wood's mine in Lancaster county, perhaps because of the more extensive quarrying in it. Dolomite is abundant, sometimes in peculiar crystallizations. The following also have been found, Breunnerite in fine crystals, chalcopyrite, bornite, magnetite, tremolite, staurolite, actinolite, chalcanthite, epsomite, Millerite, apatite and Hallite. Southwestward of the Schuylkill it appears at numerous outcrops ending on the Black Rock road about a mile northeast of Bryn Mawr.

THE CRESHEIM CREEK OUTCROP, AND SMALL OUTCROPS NEAR MEDIA.

Near the mouth of Cresheim creek on the Wissahickon in Fairmount Park, Philadelphia, are two small outcrops of actinolite and antholite. The southeasterly, about 700 feet S. E. of the mouth of Cresheim creek, is well known. It lies about two miles southeast of the steatite belt, and is wholly within the schists. Mr. Hall mentions a similar outcrop at the Flushing school-house in Bucks county, and excepts these from his generalizations as to the serpentines. The outcrop is immediately in the Manayunk schists, is quite insignificant and appears to be a local alteration of hornblende-like rock. About 500 feet N. W. of Cresheim creek is another similar outcrop much better exposed, which, I believe, has never been described. It appears undoubtedly interstratified in the schists with a dip of about 45° N. 40° W. The schists can be seen almost in contact (within one foot) and the dip and strike of the antholite and of the schists seem the same. The schists contain garnets and staurolite. It is with these I should class all or nearly all the outcrops southwest of the Marple Barren Hill school-house and also those southwest of Media, including a part if not the whole of the great outcrop west of Media.

In Mr. Hall's map of Delaware county published in C^5 are shown a number of outcrops of serpentine extending southwestward from the large Marple outcrop south of Newtown Square, most of them in two lines the continuation of which marks the northwestern and southeastern margins of the many adjacent outcrops west of Media. He also maps several south and southwest of the latter. It is not an easy task to map these serpentine areas, their margins are ill defined, and generally covered with soil. While, therefore, their general location may be correct, in some minor points they do not agree with my observations, but accurate mapping would require a topographical survey and numerous excavations.

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[1] Geol. of Pa., Vol. 1, p. 71.

I have visited most but not all of the minor outcrops. At some I was unable to find the serpentine, but wherever found it was apparently a small bed of hornblende-like rock interstratified in the Manayunk gneisses, altered more or less into antholite, steatite, serpentine and honeycomb quartz, except the outcrop on the east bank of Ridley creek northwest of Media where there is unaltered enstatite, also apparently a narrow interstratified bed.

On Mr. Hall's map a small area of serpentine is shown as almost a continuation of the great Marple outcrop and both are represented to be in the schists. I believe the Laurentian to bound the Marple serpentine on the northwest as it certainly does a short distance to the northward. Between the two areas intervene Chestnut Hill schists with the characteristic quartz in large quantity. The rocks of the small area are steatite and antholite and very unlike the enstatite and hard black serpentine of the large outcrop.

At this locality and southwestward many of the outcrops of serpentine are accompanied by outcrops of a granite, or granulite, often coarse, sometimes fine grained, containing orthoclase, oligoclase, quartz and mica, the latter in small quantity but at times in large crystals, the quartz also in small quantity, the mica being rarely disseminated. This will be more fully described in the consideration of the Media outcrop.

THE LARGE OUTCROP WEST OF MEDIA.

This outcrop, or rather series of outcrops, occurs in or on the borders of an elevated table-land, occupying the greater part of the area lying between Ridley and Chester creeks, extending southwardly a little south of the railroad from Philadelphia via Media to West Chester. On the northwest, the road from Lenni, through Lima, to Sycamore Mills is on it, but near the edge, while on the north, Dismal Run marks the boundary and on the east, Ridley creek. Within this area are several outcrops of serpentine, and scattered over a large part of its surface, amidst the soil, is the honeycomb quartz which usually results from the alteration of serpentine. This has given rise to the impression that the underlying concealed rock is serpentine. On Mr. Hall's map certain areas are marked serpentine without question, and between the areas so marked the map is lined green. My observations are that in much of the area colored serpentine, while that rock may exist, it constitutes but a small proportion of the area, while in much of the lined portion serpentine does not exist. It is true that it is impossible to define the areas of serpentine and other rocks in the table-land. The covering of soil is deep and the exposures very few, but there are some that throw much light on the structure. The region lies directly in the strike of the schists so well exposed near Media and north of it and resembling the Manayunk series. Mr. Hall, as already stated, believes these schists to lie at low angles and to overlie the harder gneisses which appear over a large area further west, but in the cut at Media, which Mr. Hall quotes in support of this,[1] the alternations of differing materials certainly dip about 70° to 90° southeast and I think this steep dip is the rule, with very few exceptions.

The only section through this table land, and that by no means satisfactory, is afforded by the excavations of the railroad, which crossing the valley of Ridley creek by a very high bridge, passes southwestward to Chester creek at a grade usually below the level of the adjacent land. Decomposition of the rocks has, however, gone on to so great a depth, that undecomposed rock is rare, and the walls of the cuts, in many places are little more than loam, but there has evidently been no transporting of material, the rock having decomposed in place. Usually the falling down of the upper part of the slopes obscures the lower, but the excessive and violent rains of the past season have washed the sides so that the rocks are very clearly exposed, the stratification is clear and distinct, and the sections are as convincing as if of hard rock. Indeed the opportunity for observation is exceptionally good.

On the west bank of Ridley creek the railroad enters a cut about a hundred yards from the bridge. This is in schists much like those on the east with a strike about N. 40° E. and a nearly vertical dip. The strike and the railroad tangent are here nearly parallel, the railroad bearing 5° or 10° north of the strike going westwardly. Here may be seen some very hard compact gneiss, both granitic and hornblendic, interstratified in the schists. About a mile from Ridley creek, a short distance west of Elwyn station, the schists are very feldspathic and dip 70° to 90° southeast. West of this is a deep cut, the schists continuing very feldspathic with coarse crystalline feldspar in thin beds, all much decomposed, some hornblendic gneiss and some included quartz, and some massive beds of a granite almost granulite, the strike and the dip about the same. Suddenly, on the north side of the cut, honey-comb quartz appears, followed by serpentine, and this by a coarse hornblende rock, containing grains of a yellow mineral, probably chrysolite, and this is followed by serpentine to the end of the cut probably 200 feet.

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[1] Vol. C ^{5} p. 59.

On the south side of the railroad the feldspathic schist continues without a trace of serpentine, but the hornblendic rock does appear on the south side. This will be referred to hereafter.

West of this, the ground is lower, and there are no exposures for about a quarter of a mile to Chrome Run, which rises on the extreme northern edge of the table-land, and flows nearly south into Chester creek. On the east side of the creek are large serpentine areas, but there is evidence too of much granulite, here being the celebrated Black Horse moonstone locality. Along the creek the ground is low, but near where the State road crosses it, its bed is a granulite excessively jointed, hence easily quarried and making a good building stone. The dip and strike are not clear. On the west side of the creek at the railroad, much earth has been removed to construct embankments and here the granulite is in large quantity but poorly exposed.

On the east side of the creek a similar removal of earth lays bare a ridge of diorite, part of it very compact, part schistose, with the unusual strike N. 30° to 40° W. and a dip of 70° to 90° northeast. This is cut off by large masses of granulite striking N. 20° E., some of it fine grained, some containing large crystals of feldspar, in fact almost a porphyry. The contact is concealed, but the diorite is visible within a foot of the granulite. It would seem difficult to explain this except by regarding the granulite as intrusive, and perhaps the diorite here is similar to that of the hornblende rocks in the cut to the east before mentioned.

The close correspondence of these occurrences with the observations of the Canadian geologists as to the Black Lake serpentines hereafter mentioned is apparent.

Between Chrome Run and the next creek west is a cut, in the easterly part of which serpentine and honeycomb quartz occur. Toward the middle of the cut, decomposed granulite appears, embedded in which are masses, sometimes pebble like, sometimes bedded, of actinolite, all much decomposed. Following this the granulite is distinctly stratified, mostly regular, some of it contorted, striking S. 20° E. nearly vertical, looking much like that west of Elwyn. It contains some hornblende and actinolite. The valley of the creek beyond is quite deep, with steep banks, and the floor of the valley rises very rapidly northward. On the hill between Chrome run and this creek, near the railroad, honeycomb quartz is visible in the soil, but, going northward, schists soon appear in quantity, succeeded by masses of granulite; and this, near the source of the creek, and near the point at which the Lima road forks to Lenni on the west and to Glen Riddle on the east, gives place to honeycomb quartz. None of these rocks seem absolutely in place, but their quantity is so great, that their existence under the surface cannot be doubted.

Returning to the railroad, the next cut is that in which Glen Riddle station is located. In this the chief rock is the decomposing granulite with serpentine and honeycomb quartz, the serpentine and granulite so intermixed and so decomposed, that it requires close examination to distinguish them, but the serpentine can be seen in unquestionable granulite, and the granulite in unquestionable serpentine-like rocks. In this cut there appears to be a gentle westerly dip and the proportion of the granulite to the serpentine seems to increase as the depth increases.

The cut west of that at Glen Riddle and east of Lenni, the locality of vermiculite, actinolite, yellow quartz, Delawarite and Lennilite, shows the granulite much more massive and less decomposed than any of the preceding. This cut is a curve on the southerly slope of a steep hill, so that the south bank is comparatively low, that on the north rising steeply probably 100 feet. The top of the hill is honey-comb quartz, then there is a terrace, probably made in the grading of the railroad, apparently almost entirely granulite, and then on the slope to the railroad is granulite, some of it with crystals of feldspar an inch or more in size (Delawarite, Lennilite), some very fine grained, much of it very heavy bedded and compact, very hard and entirely undecomposed, and some of it soft and decomposed.

In this occurs vermiculite, or Hallite, and actinolite, apparently the result of the decomposition of an interbedded mineral, sometimes in lenticular masses, sometimes in narrow beds, and in some places looking as if the granulite itself had changed into serpentine. One measurement gave strike N. 45° E. dip 65° N. W. The only certain thing, however, was a general northeast and southwest strike. On the north side of the cut there was much more granulite than serpentine, on the south side more serpentine than granulite, but both were intermixed on the two sides.

In the road which skirts this hill, south of and generally lower than the railroad, the same intermixture of granulite and serpentine may be seen, the granulite greatly in excess.

In the hill northeast of the cut is an abandoned serpentine quarry. Here also the granulite occurs in the serpentine, looking more like a dyke than elsewhere except on Chrome Run, and at Crump's quarry hereafter mentioned, but the exposure does not decide the question.

West of the Lenni cut and near Lenni station, the Manayunk rocks, or rocks very like them, appear in a large quarry, the rock here being a schistose gneiss.

From Lenni and Glen Riddle roads lead northwestward and joining, run through Lima to Sycamore Mills, on Ridley creek, near Blue Hill.

On the Lenni road the gneisses appear, followed by loose masses of the honeycomb quartz; on the Glen Riddle road, the quartz only is seen at the surface, but where the underlying rock is exposed by washes in the road gutters, it is seen to be gneissic or schistose and not serpentine or quartz. The honeycomb quartz is visible along this road nearly to Sycamore Mills, in other words from near Chester creek, to near Ridley creek, but not immediately on either. About a mile west of Sycamore Mills is a road close to the Middletown public school, or the Barren Hill school-house. It covers a considerable area visible on the south bank of Dismal Run, but on the Lenni road it is not visible, the surface being a loam with intermixed honeycomb quartz.

On the Lima-Lenni road, northeast of the school-house, on the descent from the table land to Ridley creek, near the mouth of Dismal Run, the granulite suddenly appears in great quantity and evidently in place. Northwestward of Dismal Run the Laurentian with all its characters occurs in abundance, forming a steep ridge probably

200 feet high divided by a branch of Dismal Run into a smaller hill on the northeast known as Roundtop and a much longer one toward the southwest called Poplar Hill. Dismal Run seems to be the boundary between the Laurentian on the northwest and the serpentine on the southeast, flowing in a remarkably straight course about N. 60° E. The road mentioned as crossing the Lenni-Lima road at the Barren Hill schoolhouse shows the serpentine in quantity with its characteristic vegetation immediately southeast of Dismal Run, but as soon as the higher land is reached the serpentine disappears, and honeycomb quartz is found in the soil in greater or less quantity, but no rocks in place.

To avoid confusion I should state that there is another "Barren Hill Schoolhouse" in Marple about a mile and a half north of Palmer's Mills. The authorities, with characteristic economy, seem to have selected the serpentine outcrops in this vicinity as sites for Public Schools, perhaps upon the theory that knowledge would grow where nothing else would, but a worse education for the young can hardly be found than the surroundings of the three contiguous schools of Marple, Blue Hill, and Middletown. They are a disgrace to our civilization.

Eastward along this road, about a quarter of a mile from the schoolhouse, on an affluent of Ridley creek, occur great quantities of the honeycomb quartz, completely covering the ground, but even here the vegetation is not characteristic of the serpentine. About a quarter of a mile further east a steep bluff on the north of the road discloses the schists and in them a large mass of kaolinized feldspar, whether a bed or dyke is not clear. A short distance beyond, the road runs into the road from Lima to the Rose Tree Inn, and on this also the schists are seen. This brings us about a half mile northwest of our point of departure at Ridley creek and the railroad.

Examining now the more central part of the area we find on the State road, east of the road from Lima to Glen Riddle, loose honeycomb quartz, but at the foot of the hill, where Chrome Run crosses, two quarries in granulite. This rock lies in beds from a few inches to a foot in thickness, rarely more, and it is excessively jointed.

East of this is more honey-comb quartz and a little serpentine. On the same road east of the Black Horse tavern there is more quartz. About a quarter of a mile east of the tavern a small stream flows northeastwardly into Ridley creek. Its valley and the next valley to the north, form the locality known as Mineral Hill. Leaving this for a moment, we find along the road indications of serpentine and about a quarter of a mile west of Ridley creek large and abundant masses of enstatite, east of which are again the schists.

The Mineral Hill locality consists chiefly of the bed of the stream above mentioned which rises south of the State road and flows northeastwardly into Ridley creek. The descent is rapid and the stream has cut quite a gorge. Its bed is full of the fragments of the rocks, but the exposures of the rocks in place are not satisfactory. Serpentine, actinolite and granulite, the latter containing the moonstone and sunstone which have made the hill famous, are abundant. At one place the serpentine could be seen apparently interbedded in decomposed granulite.

A section on this creek where there had been a deep wash shows very much the same as in the cuts near Glen Riddle, viz.:

N. W.	1.	Granulite decomposed into fragments but the fragments hard and seemingly unaltered growing harder southeastward, strike N. 40° E. dip northwest irregular but steep.	6 feet.
	2.	Hallite (?).	6 “
	3.	Honeycomb quartz.	6 “
	4.	Granulite like (1).	3 “
	5.	Hallite (?).	2 “
	6.	Granulite decomposed.	6 “
	7.	Granulite decomposed including lenticular masses of actinolite decomposed and in same stratum 7 feet N. W. serpentine and quartz.	6 “
	8.	Hallite (?).	3 “
	9.	Granulite including lenticular actinolite.	1 “
	10.	Soft green. (Serpentine? Chlorite?).	1 “
	11.	White soft rock including curved crystals (of serpentine?).	1 “
	12.	Soft serpentine.	2 “
	13.	Hard serpentine.	10 “
	14.	Concealed.	10 “
S. E.	15.	Large masses of undecomposed granulite.	

About a quarter of a mile above the mouth of the stream is Crump's quarry. Here the serpentine, rather light in color and comparatively soft has been quarried, largely by machinery, toothed wheels rotated by steam power cutting deep grooves in the rock and forming slabs. The numerous joints in the rock cause many of these to break up into pieces too small for use, and the quarry has not been wrought for some time. The whole quarry is in serpentine, but the north wall is granulite. At the contact there is a stratum about one foot thick of soft micaceous rock like Hallite or Jefferisite. In the granulite are lenticular masses of the Hallite. Farther southeast is a section of this granulite, and there appears on the northwest, serpentine, then a thin stratum of Hallite, then granulite fragmentary, then a V-shaped mass of Hallite and fragmentary granulite, then serpentine. The strike is about N. 50° E. and the dip curves 70° southeast on the southeast side, to 80° northwest on the northwest side. Some of the granulite resembles the Leelite of southern Chester county which passes into Deweylite. This exposure is 10 or 12 feet across and the appearance is that of a dyke. About fifty feet southeast of this is a similar exposure, of similar character, with strike about the same, dip 70° southeast, and on the northwest of it, Hallite enclosing decomposed granulite.

The ravine northwest of this shows few exposures, but granulite is abundant, here inclosing sunstone and Amazon stone.

South of the Black Horse Inn is one of the largest areas of serpentine, and in this, a large quarry was wrought for many years. In this vicinity large masses of granulite are abundant, some of them containing very beautiful moonstone. Here occurs also corundum in crystals in albite, the locality being about a quarter of a mile south of the Black Horse Inn on the road to Elwyn. On this road the chief rock is the schists, with serpentine close to the Inn, and also about a quarter of a mile north of the railroad, the latter apparently not over 50 feet wide.

For brevity, I have used the term granulite to indicate the feldspathic rock so abundant in this region. Most of it is strictly granulite, a mixture of feldspar and quartz, the feldspar frequently oligoclase and greatly predominating, some of it probably containing no quartz at all. In some of it hornblende occurs but usually in very small proportion, as in the so-called granite quarries on Chrome Run near the State road. In the schistose varieties mica occurs, but it is probably absent in the compact varieties. Some of it is very fine grained, some coarse with crystals of feldspar an inch or more across, in fact a porphyry. In decomposing some of it breaks up into small angular fragments, which are quite hard, and some of it passes into kaolin, while in some places it appears to be changing into a serpentine-like mineral.

I have described the region thus minutely because my conclusions in regard to it differ from Mr. Hall's, and because the exposures at any one place are not convincing.

Mr. Hall's theory requires a lower region of schists, lying at low angles, overlaid by the serpentines in one or more synclinal basins. I have been unable to find an instance of a dip under 70°, while there are hundreds 70° and upwards.

Where the schists and granulites, and the serpentines, occur in contact, and both walls can be seen, one is included in the other in a mode precluding any theory of synclinal or anticlinal folding and to make interbedding the only possible explanation.

Whether the granulites are all stratified, or whether some of them are igneous is a more difficult question. It is certain that some of them are stratified, as in the cut west of Elwyn and that east of Glen Riddle station, but others, as on the east side of Chrome Run and in Crump's quarry, have a plutonic aspect and resemble very closely the granulite dykes which penetrate the chrysotile bearing serpentines near Black Lake and Thetford P. Q. At this place the explorations for chrysotile have well exposed the rock, which Dr. Ells of the Geol. Survey of Canada informs me is an altered intrusive diorite. Penetrating the serpentine are frequent dykes of granulite from a foot wide upwards, with the dyke character distinctly marked. The serpentine being hard and undecomposed, the effect of the dykes was apparent in slickensides and slaty, fibrous and jointed structure. Two small dykes which I examined were decomposed next to the serpentine and the whole appearance was almost a counterpart of that shown at Crump's quarry at Mineral Hill above described. Of these exposures Dr. R. W. Ells writes.

"In all these areas (Thetford, etc.) the serpentines are closely associated with the diorites, of some portions of which they are undoubtedly, in part at least, an alteration product, in contact with the black Cambrian slates on the one hand, and with hard whitish granulite on the other. The latter, which sometimes assumes the nature of a granite, frequently occurs in huge masses, or dykes, cutting the serpentine rocks both here, and at Black Lake and Thetford." Geol. Can. 1886, J. 29.

Speaking of the asbestus (chrysotile) mines of Belmine, he says:

"The serpentine is associated with considerable masses of whitish granulite * * * * in places * * * * a true granite. This appears in places to cut the serpentine after the manner of true dykes. * * It is presumable that in most cases at least the rock is to a great extent an alteration product of some form of dioritic rock rich in olivine." Id. p. 43.

I think the weight of the evidence is, that underlying this region are highly feldspathic schists inclosing beds of enstatite and perhaps other hornblende-like minerals, that through this probably penetrate dykes of granulite, that the enstatite, etc. have become serpentine and allied minerals, while the schists and granulite have decomposed. The serpentine also in many parts has changed into quartz, and this quartz now lies strewn upon the surface as the most abundant rock, simply by reason of its stability. Were a section of rock from the Glen Riddle cut spread upon land and exposed to the weather for a few seasons, probably nothing would be left but soil and the honey-comb quartz, which last would probably appear to be the chief, if not the only rock, while in fact it does not constitute two per cent of the volume. This theory would account for the excellence of the soil in most parts of this area, indeed over nearly all of it where the serpentine is not actually visible at the surface. This was well described by an intelligent farmer with whom I conversed, in the words, " where the serpentine lies deep the ground is good." I am informed that in nearly all the wells, even where the honey-comb quartz is quite abundant at the surface, the rock reached is a gneiss or schist.

In one respect this Media outcrop is anomalous. It appears to be the only one away from the Laurentian in which enstatite appears. On the east branch of Ridley creek, that is northeast of the table-land, there is a small outcrop of this rock with a strike which would carry it into the area under consideration. This enstatite is in the schistose gneisses, apparently as an interbedded mass, and is in the direct line of the outcrops arranged in line to Palmer's Mills as shown on Hall's map. The exposures are poor, but that they are all within the schists is unquestionable and with them in some cases a coarse granite is associated, apparently interstratified in the schists.

It is further true that the northwestwardly part of the Media outcrop, or rather series of outcrops, does border the Laurentian, and that the serpentine lying along Dismal Run may be a continuation of the Blue Hill serpentine, and may be entirely distinct from the southerly outcrops which are certainly in the schists.

The Serpentine of Glen Mills on Chester Creek.

Mr. Hall finds a narrow synclinal of schists with serpentine overlying the gneisses of Chester creek which he regards as Laurentian.

I have already stated my reasons for thinking these gneisses a part of the Manayunk group. A recent careful examination confirms me in this and indicates that the serpentines of this vicinity, like those farther east, are altered beds in the Manayunk gneisses.

The serpentines are shown on Mr. Hall's map as four distinct outcrops, one on each side of the creek, on a line passing N. 50° E. through Glen Mills, and two on a parallel line about three-quarters of a mile S. E. near Sharpless' feldspar quarry.

The outcrop west of the creek nearest Glen Mills is confined to a very trivial exposure in the road. That southwest of it I could not find. East of the creek were trivial exposures of honey-comb quartz loose on the surface, but I believe considerably north of Mr. Hall's line.

At Glen Mills, the topographical base of Mr. Hall's map is incorrect or the roads and railroad have been changed since it was made. The road to Sharpless' quarry is correct and the green spot at its westerly termination correctly indicates the location of the serpentine there. The railroad north of this crosses the old creek bed as shown, diverting the creek to the west side of the railroad, which, however, does not continue on the east side, but crosses immediately below Glen Mills station, and thence continues on the west side. This crossing and the station are about a half mile north of the road to Sharpless' quarry, and at this point there is another bridge over the creek connecting four converging roads, or more accurately, permitting the road along the creek to cross, going northwardly, from the west bank to the east, and a northeast and southwest road to cross the creek. It is on this last road I observed the honey-comb quartz east of the creek. On Mr. Hall's map these roads are located a considerable distance north of their true position.

Beginning at the creek about a half mile north of Glen Mills station and this bridge, at the point at which on Mr. Hall's map, trap in Laurentian is indicated, a very compact garnetiferous gneiss is found. South of this, a recent cut for a railroad to the new House of Refuge shows the same gneiss interbedded in the Manayunk gneisses, some decomposed, some not, some contorted, some regular, showing a strike about N. 20° E. with a southeasterly dip of 20° to 50°. South of this is another excellent exposure on the railroad and about here should be the northerly margin of the schist area, but the same rocks appear, and continue with constant exposures, down the creek to and beyond the Sharpless road. Close to the road and to the north of it is a quarry evidently not wrought for many years.

The hard gneisses appear in the bottom and side. The face of the quarry shows alternations of the hard gneisses with decomposed rock.

At the north wall of this quarry a very regular stratum gave strike N. 30° W. dip 50° N. E. West of this, along the railroad there is a prevalent easterly dip 45° to 70°. The strike is quite irregular, owing to contortions in the strata; N. 0° E., N. 30° E., N. 20° W. were observed.

South of the Sharpless road is low ground and a creek flowing from the northwest; south of this is a hill showing the gneiss with a cut 150 feet long through part of it. At the north end the gneiss is very massive and irregular. In the middle it is coarse and very feldspathic, over this part a southeast dip is visible, at the south end there is a northwest dip of 70° to 90° with a strike N. 60° E.

On the Sharpless road, east of Chester creek the same gneisses appear much decomposed.

Along the bottom of the creek mentioned as flowing from the northwest into the Chester creek at the Sharpless road the same gneiss is quite abundant in loose masses.

On the west bank of Chester creek close to the serpentine, no outcrops are visible but there are loose masses of the gneiss, and 300 feet south, it occurs in place.

The outcrop at Joel Sharpless' is shown as two in a line N. E. and S. W. I found but one, at the summit of a high hill about one hundred yards south of the road and approximately parallel to it (N. 70° E). The only rock visible is the honey-comb quartz but it is in large quantity over several acres of ground. The gneiss is visible in the road and occurs also in large loose masses in the next field south of the quartz.

The Sharpless feldspar and mica quarry is not to the north of the serpentine but to the southeast, and on the east side of the small creek shown on the map. This quarry is in an exceedingly coarse granite containing much orthoclase and mica, the latter crystallized, the orthoclase in the upper part kaolinized, Some crystals of the mica are more than a foot in length and breadth, but the larger crystals seem very irregular, and I am informed that much of the mica was unmerchantable. The quarry has not been wrought for years and evidently the work was not systematically conducted. Very large beryls occurred in the granite.

All the Delaware and Montgomery county outcrops close to the Laurentian are characterized by the general very dark color and great hardness of the serpentines, and by the rarity of minerals, except varieties of serpentine, and asbestus, enstatite and quartz, the latter resulting from the alteration of the serpentine. At nearly all the outcrops there is evidence, and at some of them almost absolute proof, that the serpentine results from the alteration of the enstatite. Chromite, Genthite and Ripidolite occur rarely.

The pseudomorphism of enstatite into serpentine may be most clearly seen at Rose's quarry on the La Fayette belt about one thousand feet west of the Schuylkill, where the same stratum is enstatite below, serpentine above, but rocks in process of change may be found at many of the other outcrops, especially along the great Radnor belt, also at the outcrop S. W. of Newtown Square and where the LaFayette belt crosses Darby Creek near the southwest corner of Radnor Township.

It is true that Dr. T. Sterry Hunt [1] contends that the origin of the serpentine and related magnesian rocks was to be found in deposits of hydrous silicates like the magnesian marls of the Paris basin and that the enstatite, etc. are derived from the serpentine.

In the region under discussion, the evidence is that the enstatite and the serpentine are pseudomorphous one of the other. Inasmuch as there frequently occur serpentine pseudomorphs after other minerals, in which the crystalline form of the original mineral is present, *e. g.*, after chrysolite, enstatite, staurolite, pyroxene, hornblende, etc., while there is no evidence whatever that any of these minerals, or probably any others, except quartz, have resulted from the decomposition of serpentine, I incline to the other view. This is supported too by the mode of occurrence. The enstatite at Rose's quarry on the Schuylkill opposite LaFayette station is found at the bottom; as the stratum rises it can be seen to be more and more changed gradually until, near the top, true serpentine results and the enstatite disappears. There is, throughout, evidence of great pressure in a slaty structure and slickensides, proof that the forming mineral occupies the greater bulk, which would be the case if serpentine is the resulting mineral. Enstatite being a crystalline mineral would it not, if formed by dehydration from a hydrous magnesian silicate change abruptly into more or less crystalline masses rather than in the uniformly progressive mode in which we find it, whereas the latter is exactly as we should expect to find hydration occur.

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[1] Min. Phys. & Phys., p. 432.

It will be instructive in this connection to quote observations of of Dr. Genth and others in regard to these and like serpentines.

Speaking of the corundum of Chester, Mass., Dr. F. A. Genth[1] says:

"The whole deposit lies in a talcose slate and serpentine between gneiss and mica slate in the centre of the Green Mountains."

Dr. Genth [2] shows that the chromiferous and nickeliferous serpentines and talc slates owe their existence to the decomposition of chrysolite rocks.

> " In Pennsylvania, where the unaltered chrysolite rock has never been observed, a rock has been found which is its representative and contains the same constituents, only in different proportions. In North Carolina the granular chrysolite always contains small quantities of enstatite (bronzite), in Pennsylvania on the contrary we have an enstatite (bronzite) rock containing small grains (from 5 to 10%) of chrysolite. It is best developed at Castle Rock, Delaware county, also near Wood's Chrome Mine in Lancaster county.
>
> In all the chrysolite rocks small grains or crystals of chromite are disseminated through the mass of the rocks; in the serpentine, which has resulted from the alteration of the chrysolite, these crystals or grains are still present and give evidence of the original mineral " [3]

Dr. Julien [4] writing of the dunyte beds of N. C. says, " the dunyte beds are everywhere and exclusively found inclosed in a stratum of hornblende gneiss black and slaty. This forms the upper layer and largely occupies the central zone of the mass of gneisses and schists entirely of types identical with those found in the White Mountains of New Hampshire."

Dr. R. W. Raymond, [5] speaking of the Jenks corundum mine in Macon Co., N. C., and quoting Prof. Kerr says, " This mountain tract of Laurentian rocks * * * along the middle of the belt now specially under consideration a discontinuous line of outcrops appears at intervals from Cane creek in Mitchell county through the intervening counties of N. C. into Union county, Ga. These are called in the State Geological Report dykes of chrysolite or dunite," and adds, " I should not be surprised if future careful study of all the localities should show these chrysolite beds to be intercalated members of the formation in which they occur."

He then concludes as a result of his studies that the rock is undoubtedly sedimentary in character, the dunyte sometimes interbedded in the gneiss in large layers one to six meters in thickness and that four modes of alteration of this dunyte occur, viz.:—

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[1] Am. Phil. S.. September 19th, 1873.

[2] Sill. Jour. Vol. 2, pp. 111–202.

[3] Dr. Genth, Am. Phil. So., Aug. 18th, 1882, page 394.

[4] Proc. Boston Soc. of Natural History, Vol. XX, p. 11, Dec. 6th, 1882.

[5] Trans. Am. Inst. M. E. 1876.

1. Chalcedonic. "When all the bases have disappeared and the chalcedony remains as an exceedingly cellular mass of thin scales and plates parallel or anastomosing with the greatest irregularity, a chalcedonic schist or siliceous sinter is the result, often bearing some resemblance to a buhrstone."
2. Hornblendic. "The final result is a green actinolite rock or schist or grayish-white amphibolyte or tremolyte schist.
3. Talcose.
4. Ophiolitic.
5. Dioritic."

One prominent feature of the most of the Pennsylvania outcrops above described is the abruptness of their appearance and disappearance, in this respect resembling far more plutonic masses than interstratified beds or synclinal basins. If interstratified they should be somewhat lenticular in outline. If synclinal the adjacent dips being steep as seems to be always the fact they should also show a more or less lenticular or boat-shaped outline. On the contrary, where exposed they often appear abruptly and end abruptly, well shown at the outcrops east and northwest of Radnor station, on the Radnor and Chester road near Darby creek, in Marple, at Blue Hill where a hill or ridge of considerable height is serpentine to the southwest bounded by Laurentian on the northwest and wholly Laurentian on the northeast, the strike of the Laurentian being nearly south, that of the hill nearly northeast and southwest.[1] Nevertheless the position of the serpentine belts close to the Laurentian on the one side and with mica and hornblende schists on the other, seems to forbid our regarding them as intrusive rocks. The subject is beset with difficulties but the theory of interbedding, notwithstanding the difficulty of explaining the want of continuity and the abrupt appearance and disappearance, seems the only one tenable. It is true that the great Conshohocken trap dyke strikes almost with the adjacent rocks, but nevertheless it does not do so exactly, its bearing westwardly being more southerly, so that at the Schuylkill it is in the hydromica schist of the South (Chester) Valley Hill. It then cuts at a very acute angle the limestone, Potsdam and mica schists of Cream

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[1] The outcrops of the Radnor-West Chester belt are on a line nearly east and west but the outcrops themselves all cross this line bearing more N. E. and S. W. except that northeast of Radnor station.

Valley, reaching the Laurentian at Devon, southwestward of that seeming to retain no longer its rectilinear aspect.

I believe, therefore, that there are in this region certainly two, and perhaps four horizons of serpentine; one in the Laurentian, a second, perhaps in, but certainly if not in, almost immediately above, the Laurentian, a third of altered schists, probably a synclinal in mica schists of the Chestnut Hill series and the fourth altered hornblende-like rocks in the Manayunk schists. It may be that the first should be grouped with the second, and the third with the fourth. It would seem probable that at the close of the Laurentian period in this region magnesian silicates were abundant, possibly derived from the trap rocks so common in the Laurentian of Delaware County, or from volcanoes whose existence the trap dykes indicate; that subsequently, portions of the rocks were eroded and probably sorted by wave action, and owing to their high specific gravity formed beds in the more recent schists similar to the magnetite beds of the Laurentian.

As to the age of these schists much more must be learned before we can feel any certainty. Lithologically they are Montalban and Huronian, but if there is no fault and the sandstone at Waverly Heights and vicinity is Potsdam, the schists adjacent to the Laurentian are of that age or more recent. This the exposure on the Paper Mill road at Chestnut Hill seems to confirm. I have seen no evidence of the supposed fault and much to lead me to believe that it does not exist—at least that it does not exist as an extensive fault. Minor faults are common.

The belief that the Potsdam is absent west of the Schuylkill has, I believe, led to this error and to the connecting of the North (Chester) Valley Hill with the Barren Hill ridge[1]; whereas they are, apparently, as shown on the map in C^6, parts of the opposing legs of a synclinal underlying the Chester–Montgomery limestone valley, and my observations make the structure west of the Schuylkill almost precisely that shown in C^6, at Spring Mill, viz., going northwest from the 1–Laurentian; 2–Rogers' altered primal; 3–Potsdam; 4–limestone No. 2 of Cream Valley; 5–Hydromica schist (South Valley Hill); 6–Limestone No. 2 (of Chester Valley); 7–Potsdam of

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[1] Prof. Lesley, Notes of the Geol. of the Schuylkill river, 1884, p. 6, says: "On the east side of the river at Spring Mills the limestone is evidently faulted against the azoic rocks of the Philadelphia belt." But the visible succession is southeast, 1–Laurentian, 2–Roger's altered primal, 3–Potsdam sandstone, 4–limestone, 5–hydromica (with trap), 6–limestone, 7–Potsdam northwest.

North Valley Hill, 8–Conglomerate probably lower Potsdam, 9–Laurentian. Nos. 2 and 8 are not on the map in C^6. This would indicate a broad synclinal, the Laurentian at the base, the hydromica schists at the centre and the limestones of Cream Valley and of the Chester Valley identical.

There is one fact not easy of explanation. The South Valley Hill on a line from Radnor station to the King of Prussia is over two miles wide and is a broad elevated table-land. Close to this line two valleys begin, draining northeastward, dividing the table-land into three hills. Of these the middle and the northernmost end west of the Gulf road, forming promontories projecting as it were into bays. East of these promontories the whole region is limestone. The southernmost division of the hill preserves its elevation and crosses the Schuylkill at Conshohocken, but it is less than half a mile in breadth.

Now if the limestone were in strata nearly horizontal, we could readily explain this by supposing a deposition subsequent to the elevation and denundation of the hydromica, but on the contrary all observable dips are vertical or nearly so. This seems opposed to the theory of a simple synclinal.

Is it possible that the limestone underlying the hydromica has been folded and crumpled up with it, in minute compressed anticlinals and synclinals like that exposed on the Schuylkill below Potts Landing, that the hydromica has been removed by erosion, leaving the ridges of limestone? This is but conjecture. The structure, however, is quite evident, and no other explanation seems to satisfy the conditions.

In the cut of the Pennsylvania Schuylkill Valley Railroad through the hydromica schist hill at Conshohocken, what appeared to be decomposed hydromica schist was underlaid by limestone.

In this connection may be mentioned the fact that the basin of the Conshohocken Water Works, on this hill of hydromica schist, has two or three times suddenly emptied itself through holes in the bottom without visible outlet—easily explicable if the limestone underlies, but difficult otherwise.

If the hydromica schist overlies the limestone, then the sandstone on the north side of the hydromica hill, and on the south side of the Chester Valley cannot be Potsdam, as Prof. Rogers, Prof. Lewis and the writer supposed, but must be more recent.

Except the Conshohocken trap dyke, and the numerous dykes of the Laurentian, mostly small and apparently of limited length, I have nowhere found trap in the region. I have visited the localities at which the trap is shown on the map in Vol. C^5 except Howellville, Delaware county, which is in Laurentian, and I believe that on Chester creek and also on Colleen brook near Darby creek a very compact gneiss has been taken for trap.

In the schists and gneisses east of the porphyritic and especially in the Fairmount gneiss the granite is usually segregated, but it is probable that intrusive masses occur.[1]

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[1] 2nd. Geol. Survey of Pa. Ann. Rep. 1886, IV, 1602, & plate 1570.